PL-TR-95-2020

SPACE PROBE DATA PROCESSING

Eben Hiscock
Robert Rose
Paul Whitman

RMS Technologies, Inc
4221 Forbes Road
Lanham, MD 20706

31 December 1994

Final Report
1 October 1990-31 December 1994

PHILLIPS LABORATORY
Directorate of Geophysics
AIR FORCE MATERIEL COMMAND
HANSCOM AIR FORCE BASE, MA 01731-3010

"This technical report has been reviewed and is approved for publication"

ALAN R. GRIFFIN
Contract Manager
Data Analysis Division

ROBERT E. McINERNEY, Director
Data Analysis Division

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
31 December 1994

3. REPORT TYPE AND DATES COVERED
Final 01 OCT 90 - 31 DEC 94

4. TITLE AND SUBTITLE
SPACE PROBE DATA PROCESSING

5. FUNDING NUMBERS
PE: 63402F
PR: 7659 TA: 05 WU: AD
Contract F19628-90-C-0193

6. AUTHOR(S)
Eben Hiscock, Robert Rose, Paul Whitman

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
RMS Technologies, Inc.
4221 Forbes Road
Lanham, MD 20706

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Phillips Laboratory
29 Randolph Road
Hanscom AFB, MA 01731-3010

Contract Manager: Alan Griffin/GPD

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
PL-TR-95-2020

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report discusses the design, development, modification and implementation of telemetry data processing techniqeus and computational routines for processing large volumes of datatelemetered from space probes. The original design of the Orbital Data Processing System (ODPS) supported the Combined Release and Radiation Effects Satellite (CRRES) Program. The ODPS was modified to support the Advanced Photovoltaic and Electronics Experiment (APEX) Satellite. The ODPS was again modified to support the Miniature Sensor Technology Integration (MSTI) Satellite Program. The APEX ODPS and the MSTI ODPS were used successfully during the period of this effort. The Telemetry Data Processing System (TDPS) was substantially upgraded during the period of this effort.

14. SUBJECT TERMS
Telemetry Data Processing System; CRRES; APEX; MSTI; Orbital Data Processing System

15. NUMBER OF PAGES
52

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

TABLE OF CONTENTS

LIST OF FIGURES

1. OVERVIEW

1.1 Introduction

Contract F19628-90-C-0193 was awarded to RMS Technologies, Inc. on 1 October 1990, for a period of 3 years. This contract was to conclude on 30 September 1993. The contract was subsequently extended through 30 September 1994.

The main thrust of the effort under this contract was grouped into 6 different tasks. These tasks were:

1) Complete the processing of the space probe telemetry for the Combined Radiation and Release Effects Satellite (CRRES).

2) Design, develop, test and implement telemetry processing techniques and computational routines to process large volumes of data and generate agency tapes containing sensor, orbit, attitude, and pitch angle information for the Advanced Photovoltaic and Electronics Experiment (APEX).

3) Design, develop, test and implement telemetry processing techniques and computational routines to process large volumes of data and generate agency tapes containing sensor, orbit, attitude, and pitch angle information for the second Miniature Sensor Technology Integration Satellite (MSTI-2).

4) Begin the initial design concepts for the third Miniature Sensor Technology Integration Satellite (MSTI-3).

5) Acquire (ACQ) and quality check (QC) the data telemetered from other space probes.

6) Operate and maintain the Telemetry Data Processing System on site at PL/GPD Hanscom AFB, Bedford, MA.

These tasks were performed by the RMS Technologies Inc. (RMS) Support Team under the direction of the Data Analysis Division of the Geophysics Laboratory (PL/GPD) and the Contracting Officers Technical Representative (COTR), Mr. Alan Griffin.

The RMS Support Team consisted of:

Program Manager	Eben Hiscock
Sr. Computer Analyst	Stephen Wooten (CALCULEX)
Computer Analyst	Robert Rose
Computer Programmer	Michael Delorey
Sr. Elect. Tech.	Henry Whitman III
Data Clerk	Salim Kamthewala
Orbital Analysis	Bill McNeil (RADEX)

1.2 Historical Data

Initial work for the CRRES Satellite Space Probe Telemetry Task was performed under the preceding contract titled "CRRES Project Orbital Data Processing Task" contract number F19628-87-C-0031 which was awarded on 7 January 1987 for a period of three years and subsequently extended through 30 September 1990. Under this contract, the RMS Team successfully designed, developed, tested and implemented the telemetry processing techniques needed to process large volumes of data generated by the CRRES Satellite and produce necessary agency tapes containing the required sensor, orbit, attitude, and pitch angle information. Support for the CRRES Satellite continued under contract F19628-90-C-0193.

The basic concepts and software developed during the design and operation of the CRRES Satellite Orbital Data Processing System were modified and improved to support the APEX Satellite and the MSTI-2 Satellite.

Software modifications were necessitated by the different experiments flown on the APEX and MSTI-2 satellites. Additional changes were made to the basic software to improve quality and efficiency and thereby reduce the cost of the agency data files and agency data tapes distributed to the experimenters.

1.3 Space Probe Data Processing

The processing of space probe and satellite telemetry data was tailored to meet the unique requirements of the mission. Factors such as the telemetry system used, onboard data storage methods, number of instruments, number of principal investigators, data collection scheduling, initial data capture methods, data rates and quantity, trajectory or orbit, spacecraft control, spacecraft attitude and magnetic field determination, merging of ancillary data, data distribution methods, and system latency, all affected the design of the Telemetry Data Processing System and its operation.

The space probe data was processed at PL/GPD using the PL/GPD Orbital Data Processing System (ODPS) to create the agency files and Agency Data Tapes

(ADTs) that were distributed to the various agencies. The ODPS was divided into six functions. These six functions were:

1) Telemetry Data Processing (TDP)
2) Ephemeris Computation (EPH)
3) Telemetry Unpacking (TUP)
4) Attitude and Magnetic Field Processing (AMF) or Attitude Processing (ATT)
5) Agency Tape Generation (ATG)
6) Data Flow Control (DFC)

These functions will be described in a generic way in this section of the report. The specific space probe details will be covered in each of their respective sections.

Serial Pulse Code Modulation (PCM) Telemetry data was transmitted from the satellite and recorded on Inter Range Instrumentation Group (IRIG) standard magnetic tapes (analog tapes) at the various (Automated) Remote Tracking Stations ((A)RTS). These tapes were then mailed to PL/GPD for processing. The approximate number of analog tapes received at PL/GPD for processing for the CRRES Satellite was 90 per month. The approximate number of analog tapes received for the APEX Satellite was 130 per month. The approximate number of analog tapes for the MSTI-2 Satellite was 150 per month.

When each analog tape was received at PL/GPD, the PCM telemetry data stream was decommutated, quality checked, edited, merged with IRIG Universal Time (UT) code, and formatted into 100% Telemetry Data Files on disk using the Telemetry Data Processing System (TDPS). The 100% Telemetry Data Files were also archived on 8mm EXABYTE tapes in the event that reprocessing was necessary.

1.3.1 Telemetry Data Processing System (TDPS) Function

The primary function of the PL/GPD Telemetry Data Processing System was to process telemetry data, recorded from the space probe, which arrived on magnetic tape in frequency modulated (FM), and pulse code modulated (PCM) formats. The frequency modulated data was discriminated to its original state then sampled, analog-to-digitally converted and stored on disk for data analysis.

The PCM data was then processed by a bit synchronizer which reshaped the data into NRZL format and created a phase compatible clock at the proper bit rate. It was then processed by the frame synchronizer which organized the data into words of proper length and then output these words in parallel using the recognition of a unique frame synchronization pattern embedded in the original serial PCM data stream as its reference.

The data was then sent over a bus to either a computer buffer data channel and/or to a word selector for D/A conversion for display on strip chart recorders. The actual path of the data was in accordance with the work request form initiated by the individual scientist. The data and Universal Time were merged in the processing operation by the TDPS software.

The data output products were then quality checked and statistics were determined. If any anomalies or perturbations were found, they were documented and provided as part of the deliverable. The goal was at least 99% data recovery. If the data source was at fault, requests were made for alternative sources.

The Telemetry Data Processing System was designed to handle a wide variety of space probes. However, different space probes have varied and unique processing requirements, and APEX and MSTI were no exception. The APEX TDPS used a different format for each of its numerous experiment files. In addition, the experiment files contain different data packet sizes, number of packets per minor frame, subframe ID locations, and Universal Time (UT) increments, and UT locations. The MSTI-2 TDPS used two different formats: 1) a low-rate format with up to 8 minor frames; and 2) a high-rate format with 256 minor frames. TDPS support involved the modification, enhancement and maintenance to accommodate the varied and unique processing requirements of different space probes. The implementation and maintenance of TDPS was especially critical to the PL/GPD mission, since an inadequate effort in this area would translate into lost data, poor throughput, or poor quality of recovered data.

Manpower utilization was as follows:

1) The Senior Electronic Technician performed all maintenance and repair functions.

2) The Data Clerk performed computer operations and administrative duties.

3) The Programmer and Computer Analyst provided upgrades to data processing routines.

4) The program manager served as the System Electronics Engineer, provided overall supervision of personnel, and was the point of contact on site at the Phillips Laboratory.

5) The orbital analyst ensured that all state vectors received at PL/GPD were correct, produced the Ephemeris File for each satellite period, and created the required Attitude (and Magnetic Field) Processing File.

The processing was controlled by programs which were loaded into the TDPS and called from the operator's terminal. The operator directed the flow of data from input to the final output product. The time code was extracted from the data input source and combined during data processing.

Processing PCM data of questionable quality required a great deal of knowledge and understanding of the decommutation process. Data retrieval was enhanced by selecting the proper filter types and loop widths in the frame synchronizer.

Scientific data must be time correlated to be meaningful, therefore, time code quality was of prime importance. The techniques of proper generation, recording, reproduction and translation were optimized. The selection of recording format and tape speed enhanced the ability to recover usable time code.

1.3.1.1 Operating and Maintaining the TDPS

The task of operating and maintaining the PL/GPD Data Systems Division Telemetry Data Processing System on a daily basis was broken down into three main areas, administrative duties, technical duties and operational duties, as follows:

<u>Administrative Duties:</u>

a) Maintain a daily log of the data processing system operations
b) Create and maintain analog and digital tape libraries
c) Maintain the work request for the Data Analysis Division for all telemetry data processing tasks
d) Maintain required stock levels of magnetic tape (analog and digital), strip chart recording paper, and printer paper
e) Perform periodic inventory of KGR Decryption Unit and internal decoding keys

<u>Technical Duties:</u>

a) Perform periodic calibration of equipment
b) Perform periodic cleaning and demagnetization of tape recorder heads
c) Provide repair of electronic data processing equipment
d) Provide design and test capabilities for interface modules
e) Maintain Instrumentation Tape Recorder at remote sites

Operational Duties:

a) Perform required remote setup of data processing hardware by using TDPS software
b) Operate and perform file maintenance for TDPS on the VAX 4000 computer
c) Install and maintain TDPS upgrades
d) Receive telemetry data input from analog or digital tapes, process the telemetry data and provide quality checked, aligned, time correlated digital data on disk files and digital tapes
e) Process Pulse Amplitude Modulated (PAM), Frequency Modulated (FM), or Pulse Code Modulated (PCM) data as required. Provide digital to analog (D/A) conversion of data for display on strip charts
f) Use time code generators to create proper time codes for data regeneration
g) Use time code translators to translate time code from the input data tapes for inclusion in the data processing
h) Copy digital tape files to disk or digital tapes
i) Provide summary records showing statistics from the data processing for inclusion in progress reports
j) Process encrypted scientific data received from Air Force/NASA scientific satellites using classified KGR62 Decryption System
k) Provide PCM code conversion for optimum encoding and decoding of data
l) Provide signal conditioning/isolation/level shifting of signals (for RS488)
m) Create copies (dubs) of data tapes for external organization.
n) Archived digital tape files to 8mm EXABYTE in the event that reprocessing is required

1.3.1.2 Data Encryption

The NRZ telemetry data stream was encrypted with a module that was internal to the Space-Ground-Link Subsystem (SGLS) transmitter. The data received and recorded at the (A)RTS must be decrypted to allow for normal processing. During data processing by the Telemetry Data Processing System at PL/GPD, the output data stream extracted from the (A)RTS tape was passed through a PCM Bit Synchronizer (EMR8320) to obtain the Non Return Zero Level (NRZL) data and clock components. These signals were then fed into a KGR62 Decryption Box and the decrypted outputs returned to the normal PCM processing hardware (EMR 8330 Frame Synchronizer and Parallel Data Formatter) with both NRZL data signal and its synchronized clock. The care of these signals was essential to the success of recovering

the maximum quanity of data especially as the data rate approached 1 Mbps or greater.

1.3.2. Ephemeris Computation (EPH) Function

Orbital elements consisting of position and velocity vectors were received periodically from Space and Missiles System Center, Detachment 2 (Consollidated Satellite Test Center (CSTC)). These orbital elements were used by the Ephemeris Computation (EPH) Function Software to create a time history of the satellite's ephemerides. This history consisted of standard ephemeris data, satellite ephemeris data, solar/lunar ephemeris data, model magnetic field parameters and coordinate conversion data at uniform intervals during a fixed period (e.g. day-by-day, orbit-by-orbit, ect.).

A sufficiently large number of these vector sets were required to allow for intercomparison. Perhaps one week's worth, including a previously accepted vector set, were entered into a program which computes the mean Keplerian vector sets characterizing the orbit from the positions and velocities.

Depending on the vector set, it should either remain constant (e.g. eccentricity) or progress uniformly (e.g. perigee or ascending node) with orbit-to-orbit variations that were predictable from analytical orbit theory. In this way, the correctness of the data entry and soundness of the individual vector sets themselves were verified. Through the use of this program, elements that vary significantly from the mean were rejected.

A summary quality control plot of the Keplerian vector sets were then , at the discretion of the orbital analyst, appended to the State Vector Library File. The Ephemeris System was then executed to create all possible ephemeris files from the available elements. The system also updated the Orbital Data Library File giving the start and stop times of each space probe period. These were used in the definition of the time spans that were included in the Agency Tape Files.

A quality control plot was then made of each ephemeris file and, when approved, the orbital processing system library was updated to indicate: (1) that the ephemeris file for this particular orbit was available for use and (2) the day and time to begin and end the telemetry unpacking for this orbit. A sample ephemeris file quality control plot is depicted in Figure 1

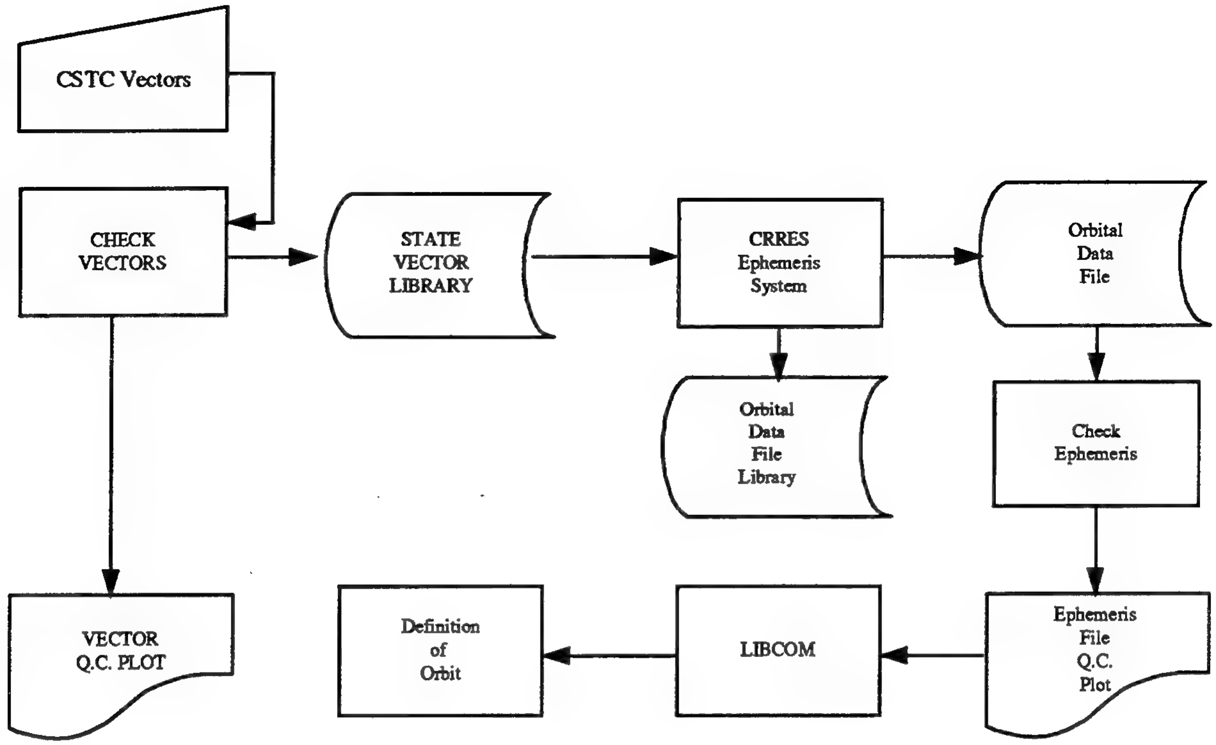

Figure 1 Ephemeris Processing for ODPS

1.3.3. Telemetry Unpacking (TUP) Function

The data for each experiment was extracted from the 100% Telemetry Data Files, time correlated and packed into Agency Files by the Telemetry Unpacking (TUP) Function Software. In addition to the Agency Files, the TUP Function also time correlated and unpacked auxiliary spacecraft data contained in the 100% Telemetry Data Files. This data consisted of spacecraft State of Health (SOH), raw attitude data, raw magnetic field data, command history data, error log data, real-time data, ect.

The raw attitude data was created from the attitude sensing elements on board the spacecraft, and provide sun angle, earth horizon crossings, and magnetic field measurements. These time correlated inputs were used by the Attitude Processing (ATT) Function to create the Attitude Fit Coefficient File.

When available, the spacecraft magnetometer (part of the vehicle attitude system) provided magnetic field measurements for use by the Attitude and Magnetic Field Processing (AMF) in plotting the magnetic field with reference to the spacecraft frame, and for pitch angle determination.

The MSTI-2 Orbital Data Processing System (ODPS) required the addition of calibration coefficients used to calibrate the Short Wave InfraRed Camera and Medium Wave InfraRed Camera on board the MSTI-2 Satellite.

These Agency Files were combined with the ephemeris, attitude and, when applicable, magnetic field data files to create the Agency Data Tapes (ADTs) by the Agency Tape Generation (ATG) Function software.

The Data Flow Control (DFC) Function managed the processing of the (A)RTS tapes and the generation of the ADTs through the ODP System. In order to manage these tapes, this function maintained and updated state vector, Flight Data Recorder (FDR) Log and period status information, and tracked the progress of the generation of Agency Files and the ADTs for each Satellite (CRRES, APEX or MISTI-2) Period. This information was combined to produce a time history of the major activities and progress in generating Agency Data Tapes for the Satellite Mission. This function also created the necessary initialize files and execution files for the TUP Function, the AMF Function and the ATG Function.

The ODPS analytic routines to perform these tasks were previously designed, developed and implemented for the CRRES Project under Contract F19628-87-C-0031, and for the APEX and MSTI-2 Projects under Contract F19628-90-C-0193.

1.3.4 Attitude and Magnetic. Field Processing (AMF) Function

The attitude portion of the AMF Function uses the raw attitude data provided by the TUP Function to create the Attitude Fit Coefficient File for inclusion in each Agency Data Tape. Software support programs are also provided to the experimenters to aid in use of these coefficients when needed to determine instrument line of sight (LOS). The Attitude Fit Coefficient File is quality checked and a summary report is included in the Agency Tape Bulletins.

The magnetic field portion of this function produces average magnetic field coefficients to be included as part of the agency data when required.

1.3.5 Agency Tape Generation (ATG) Function

The Agency Tape Generation Function writes the agency files and support files to a digital magnetic media (Agency Data Tapes (ADTs)) which are sent to each of the agencies for that program. All files written to the ADTs are also archived to 8mm EXABYTE tapes.

1.3.6. Data Flow Control (DFC) Function

The Data Flow and Control Function monitored and managed tht flow of information throughout the ODPS Task. This function also provided a wide variety of processing statistics for inclusion in the processing reports, and crated the necessary initialize and execution files for the TUP, EPH, ATG and AMF functions.

2.0 CRRES DATA PROCESSING SYSTEM (ODPS) TASK

2.1 Overview

This section contains a brief overview of the CRRES ODPS. Each of the following paragraphs in this section describes a different CRRES ODPS function. Figure 2 contains the functional flow diagram for the CRRES ODPS.

The CRRES ODP Task consisted of processing and distributing flight telemetry data to various agencies. Scientific data was collected, processed and distributed on magnetic tapes for each Geosynchronous Transfer Orbit (GTO) Period and each Low Altitude Satellite Studies of Ionospheric Irregularities (LASSII) Period.

The CRRES GTO Period was defined as a single orbit (perigee to perigee) plus a two minute overlap into the next GTO Period to ensure that there was no loss of data. The CRRES LASSII Period was defined as the time in which the LASSII instruments were on. This was generally a few minutes before perigee to a few minutes after perigee. This contract covered the period of the CRRES operations from October 01, 1990 to October 11, 1991.

The CRRES Agency Tape data contained telemetry, ephemeris, attitude and magnetic field information which was grouped into separate data products (files) and placed on the agency tapes. These data files along with the intermediate files were produceded by different CRRES ODP functions, there were eight CRRES ODP functions, there were seven CRRES ODP Functions

2.2 CRRES Orbital Data Processing System (ODPS) Task

This sub-section contains a brief description of the CRRES functions along with the names of the data items (files and tapes) produced by that function. Detailed information for each function can be found in the CRRES requirement and product specifications.

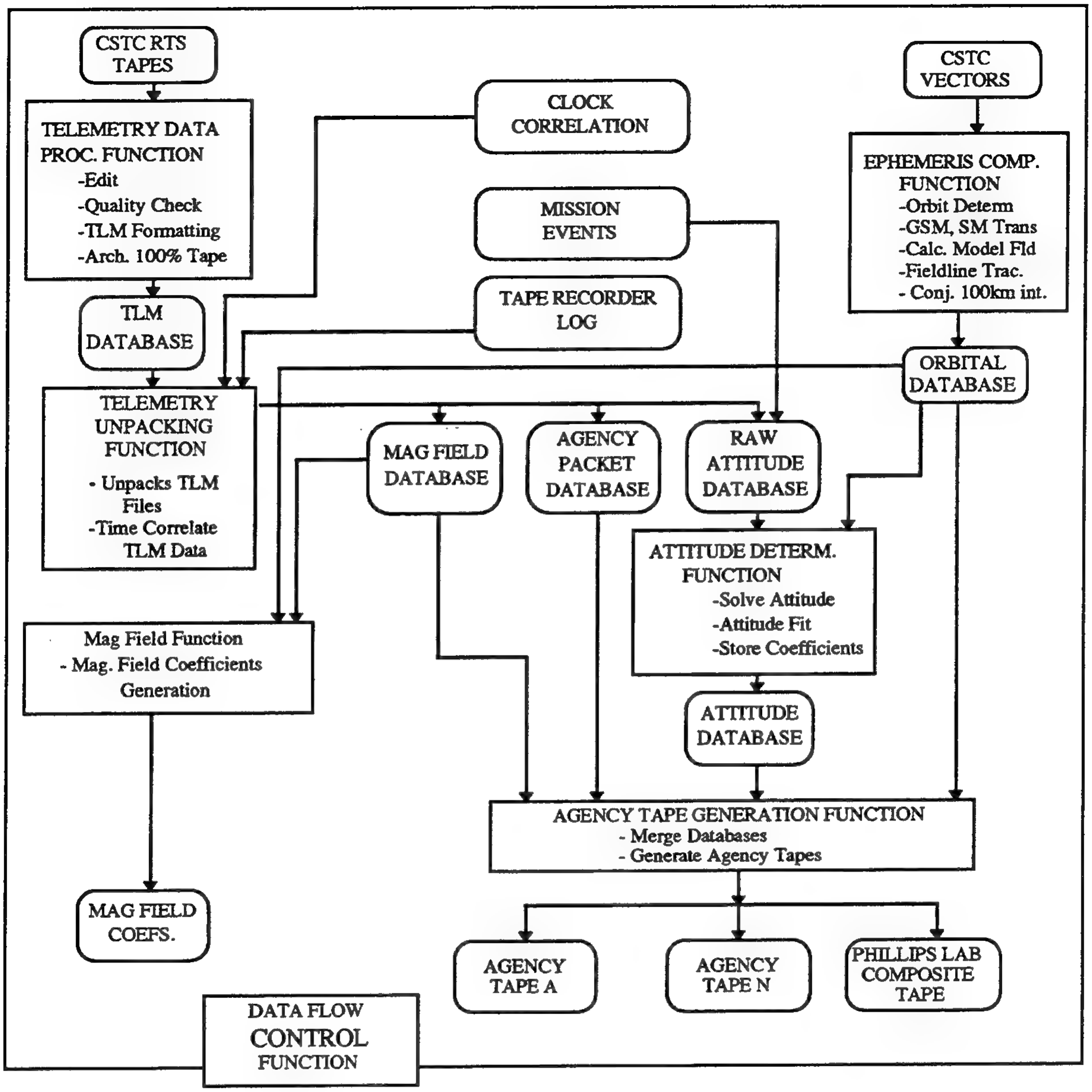

Figure 2 CRRES ODPS Functional Flow

2.2.1 Telemetry Data Processing (TDP) Function

The CRRES ODPS Telemetry Data Processing Function processed the data contained on the (A)RTS tapes to produce digital data in Major Frame Format (MFF) for a single record period. This process "1"s filled missing minor frames within major frames, listed the number of missing major frames in one acquisition pass and wrote the data to the 100% Telemetry Data File. This information was also written to a 9 track magnetic tape 100% Digital Archive Tape for storage in the event that reprocessing was necessary. There was one 100% Telemetry Data File and 100% Digital Archive Tape produced for each execution of the CRRES ODPS Telemetry Data Processing Function program.

The TDPS Archive Program was used to archive multiple 100% Telemetry Data Files to 8mm magnetic tapes in order to reduce the archive storage costs.

TDPS consolidated and improved the performance of existing data processing programs resident in the Data Analysis Division of the Phillips Laboratory (PL/GPD).

2.2.2 Ephemeris Computation (EPH) Function

The CRRES ODPS Ephemeris Computation Function used the State Vector Data to generate orbital data base information consisting of standard satellite ephemeris data, solar/lunar ephemeris data, model magnetic field parameters and coordinate conversion data at uniform intervals on an orbit-by-orbit basis. The orbital data base information was written to the Orbital Data File which in turn was used by several other Functions. A 32 bit positive integer compacted version of this file (Ephemeris File) was produced by the Agency Tape Generation Function before being transferred to the Agency Data Tapes.

2.2.3 Telemetry Unpacking (TUP) Function

The CRRES ODPS Telemetry Unpacking Function read the Telemetry Unpacking Initialize File to identify and time correlate the major frames in the 100% Telemetry Data File(s) which in turn were used to produce the following Agency Files: 1) the Agency Packet File(s); 2) the Raw Attitude Data File; 3) the AFGL Subcom Experiment; and 4) the Magnetic Field File (GTO Periods only).

The Agency Packet Files contained the serial digital, analog and bilevel telemetry data requested by each individual agency grouped into physical records. There was an integral number of major frames per physical record for each agency. Missing major frames were counted and missing minor frames "1"s filled within major frames. The UT and vehicle clock were referenced to the beginning of the first minor frame. There were ten Agency Packet Files created

for each GTO Period and three Agency Packet Files created for each LASSII Period.

The AFGL Subcom File was created for each GTO/LASSII Period. It contained the 20 subcom words from each minor frame from each major frame in a GTO Period or the 19 subcom words from each LASSII minor frame.

The Raw Attitude Data File contained the attitude related sensor readings from the 100% Telemetry Data Files collected over the GTO/LASSII Period. This file was used by the Attitude Determination Function to produce the Attitude Fit Coefficients File.

The Magnetic Field File consisted of the twelve bit raw magnetometer digital x, y, z sensor data, the eight bit magnetometer data, the eight bit temperature monitor word, three eight bit bilevel words and six spacecraft magnetometer words.

2.2.4 Attitude Determination (ATT) Function

The CRRES ODPS Attitude Determination Function used the Attitude Initialization and Operating Parameters File, the Raw Attitude Data File, and the Orbital Data File to create the Attitude Fit Coefficient File for the Agency Data Tapes.

The Attitude Initialization and Operating Parameters File contained the initialization and operating parameters used to direct the course of attitude data processing. There was a different file for each GTO/LASSII Period.

The Attitude Fit Coefficients File contained header information as well as the coefficients that defined the attitude of the CRRES Satellite during the GTO/LASSII Period.

Along with the Attitude Fit Coefficients File, this Function produced the Attitude Summary Report File, the Attitude Point History File and the Calibrated Attitude Data File. The Attitude Summary Report File and the Attitude Point History Files were used to identify and solve attitude problems detected during the creation of the coefficients. The Calibrated Attitude Data File was used as a intermediate data file by this Function.

2.2.5 Magnetic Field Generation (MAG) Function

The CRRES ODPS Magnetic Field Function used the Magnetic Field File to produce a one second average magnetic field data set which in turn was used to produce magnetic field coefficients that were sent to the agencies independent of the Agency Data Tapes. In addition to the Magnetic Field File, this function used the Orbital Data File and the Attitude Fit Coefficients File to produce the Magnetic Coefficients.

2.2.6 Agency Tape Generation (ATG) Function

The CRRES ODPS Agency Tape Generation (ATG) Function produced the actual 9 track magnetic tapes (Agency Data Tapes (ADTs)) that were sent to the agencies. In addition to the ADTs, an AFGL Composite Tape was generated. The AFGL Composite Tape contained copies of the Agency Files delivered to all of the agencies.

The files written to the Agency Data Tapes and the AFGL Composite Tape included: 1) the Agency Header File; 2) the Agency Packet File(s); 3) the Ephemeris File; 4) the Attitude Fit Coefficients File; and 5) the Magnetic Field File (GTO Periods only). The GTO agency files for a single GTO Period were written to a GTO Composite Tape and eight sets of LASSII agency files were written to a LASSII Composite Tape

As with the case of the 100% Telemetry Data Files, the TDPS Archive Program was used to archive multiple GTO/LASSII data sets to 8mm magnetic tapes in order to reduce the archive storage costs.

The ATG Initialization File contained the initialization information used to direct the ATG Function Program. This information included: 1) the tape number and name; 2) the agency name; 3) the date that the ATG Initialize File was created; 4) the GTO/LASSII Period numbers of those files transferred to tape; and 5) if the Period(s) were LASSII, the ATG Initialize File also includes the starting year, day and msecs./day, the ending msecs./day, and the next LASSII Period number.

The Ephemeris File and the Agency Header File(s) were created by this function. The Ephemeris File consisted of the Orbital Data File data records compacted into a 32 bit positive integer format. The information in the Agency Header File(s) was a combination of data in the Temporary Agency Header File and the Header Record of the Orbital Data File.

2.2.7 Data Flow Control (DFC) Function

The Data Flow Control Function controlled the flow of information through the CRRES Project Functions. The information consisted of, mission events, state vectors, time correlation coefficients, tape recorder information, analog tape information, digital tape information and information about the status of the files for each GTO Period/LASSII Period.

This information was contained in the following library files: 1) CRRES ODP Mission Event Library File; 2) CRRES ODP State Vector Library File; 3) CRRES ODP Time Correlation Library File; 4) CRRES ODP 100% Digital Tape Library File; 5) CRRES ODP Agency Tape Library File; 6) CRRES ODP AFGL Subcom

Archive Library File; 7) CRRES ODP Ephemeris Archive Library File; 8) CRRES ODP Attitude Archive Library File; 9) CRRES ODP AFGL Composite Tape Library File; 9) CRRES ODP Tape Recorder and Analog Tape Library File; 10) CRRES ODP GTO Status File; 11) CRRES ODP LASSII Status File; and 12) CRRES ODP Log File.

The following is the list of archive tapes produced for the CRRES ODPS: 1) the Ephemeris Archive Tape; 2) the Attitude Archive Tape; and 3) the AFGL Subcom Archive Tape.

The files archived on the Ephemeris Archive Tape included the Orbital Data File(s). The files archived to the AFGL Subcom Archive Tape included the AFGL Subcom Experiment File(s). The files archived to the Attitude Archive Tape included: 1) the Attitude Initialization and Operating Parameters File, 2) the Attitude Point History File(s), 3) the Attitude Summary Report File, 4) the Raw Attitude Data File and 5) the Attitude Fit Coefficients File.

This Function produced and/or updated the following initialization files: 1) the CRRES ODP Data Flow Control Initialization File for the Data Flow Control Function; 2) the Attitude Initialization and Operating Parameters File for the Attitude Determination Function; 3) the ATG Initialization File for the Agency Tape Generation (ATG) Function; and 4) the Telemetry Unpacking Initialization File for the Telemetry Unpacking Function.

2.3 CRRES ODPS Processing Summary

The CRRES Satellite was launched on 25 July 1990 and was delivering excellent quality data until its demise on 11 October 1991. The following summary includes these dates.

1323	Analog data tapes were received and logged
1245	CRRES GTO Periods were processed.
344	CRRES LASSII Periods were processed.
64	CRRES Anomaly Bulletins were mailed out listing the CRRES Periods included in the ADTs and any problems encountered during the periods.

2.3.1 CRRES ODPS Processing Summary Comments

The major anomalies for the CRRES Satellite were caused by the spacecraft clock upsets. The spacecraft clock upsets took the form of permanent clock jumps in the positive and negative direction. A study that was performed by PL/GPS to determine the cause of the clock upsets showed the upsets occurred primarily during high sun spot activity.

3.0 APEX DATA PROCESSING SYSTEM TASK

3.1 Overview

This section contains a brief overview for the Advanced Photovoltaic and Electronic Experiment (APEX) ODPS. . Figure 3 contains the functional flow diagram for the APEX ODPS.

The APEX satellite contains three principal experiments. They are the Photovoltaic Array Space Power Plus diagnostics (PASP-Plus), the Cosmic Ray Upset Experiment/Cosmic Ray Environment and Dosimeter (CRUX/CREDO), and the Ferroelectric Memory (FERRO). The Apex ODPS will convert the raw telemetry data downlinked from these experiments into computer-compatible Agency Data Tapes (ADT) that meet the processing/analysis requirements of the APEX Experimenters. There are six functions of the APEX ODPS:

Telemetry Data Processing (TDP)
Ephemeris Computation (EPH)
Telemetry Unpacking (TUP)
Attitude and Magnetic Field Processing (AMP)
Agency Data Tape Generation (ATG)
Data Flow Control (DFC)

The APEX Satellite is currently active and APEX data is being processed regualarly at PL/GPD. APEX was the first successful large scale modification of the CRRES ODPS documentation and software used to produce ADT's for the APEX Satellite.

The APEX telemetry data was recorded on Inter Range Instrumentation Group (IRIG) standard magnetic tape at (Automated) Remote Tracking Stations ((A)RTS). The serial pulse code modulation (PCM) telemetry data stream was decommutated, quality checked, edited and merged with IRIG Universal Time (UT) code, and then formatted into 100% Telemetry Data Files on disk using the Telemetry Data Processing System (TDPS) Function software. The 100% Telemetry Data Files were archived on the 8mm EXABYTE tapes in the event that reprocessing is necessary. The estimated number of analog tapes received by PL/GPD and processed by the RMS Team for APEX was about 80 per month.

The orbital elements for the APEX Satellite were provided periodically by Space and Missiles System Center, Detachment 2 (DET 2, SMC) formerly known as the Consolidated Satellite Test Center (CSTC). These orbital elements were used to create a time history of the satellite's ephemerides by the Ephemeris Computation (EPH) Function software.

An APEX Period was defined in milliseconds as 1 day plus a 20 minute overlap into the next day (0 to 87600000 msecs./ day). The exception to this was the ephemeris data which ends 30 minutes into the next day (88200000 msecs.) to ensure that there was at least one ephemeris point after the last data entry.

The attitude sensing elements on board the spacecraft provide sun angle, earth horizon crossings, and magnetic field measurements. These time correlated inputs were used to determine vehicle attitude versus time.

The spacecraft magnetometer (part of the vehicle attitude system) provides magnetic field measurements for use in plotting the magnetic field with reference to the spacecraft frame, and for pitch angle determination.

The data for each experiment was extracted from the 100% Telemetry Data Files, time correlated and packed into Agency Files. These Agency Files were combined with the Ephemeris File and the Attitude and Magnetic Field Processing File to create the Agency Data Tapes. The ODPS analytic routines to perform these tasks were previously designed, developed and implemented by the RMS Team for the CRRES Project.

Since the CRRES and APEX Satellites were similar, reconfiguring the CRRES ODPS was done with minimal effort, and without requiring a total re-design for new Space Probes. The APEX ODPS design and implementation consisted of the following steps.

1. Each function for the ODPS was successfully presented at the APEX ODPS Preliminary Design Review (PDR) in December 1991. These requirements were accepted by the Government at that time.

2. The design documents for each function were completed and presented at the APEX ODPS Critical Design Review (CDR) in April of 1992. The designs were accepted and formal coding began.

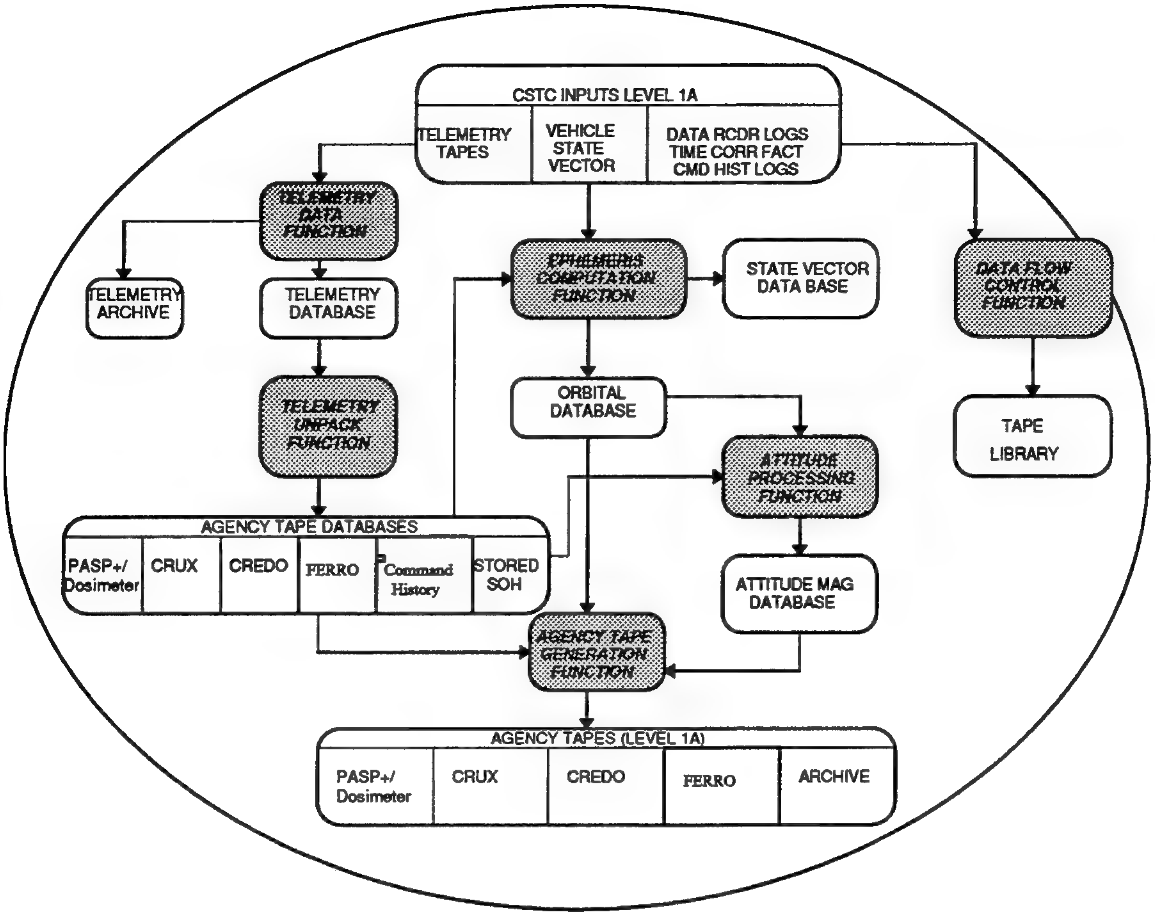

FIGURE 3 APEX ODPS FUNCTIONAL FLOW

3. The code for testprocedures for each ODPS function was completed and formal testing of each function was performed in November 1992. The Test Monitor determined that no major errors were found in each function.

4 The code for each APEX function was altered after formal testing to include the data changes that were made at (OSC). Retesting was performed in January 1993.

5. The APEX System Level Testing was successfully performed in July 1993. After testing was completed, the APEX Final Test Report was submitted and accepted by a government representative.

6. The code and documents related to APEX are now under configuration management.

7. Throughout testing of the APEX Satellite at OSC, sample telemetry data tapes have been made available for Phillips Laboratory. These tapes were processed and the results were made available to the APEX experimenters and OSC.

8. As OSC prepared for Comprehensive Performance Tests (CPT), sample data tapes were made and shipped to Phillips Lab. These tapes were being processed and analyzed, and the results were being made available to the APEX experimenters and OSC. RMS assisted OSC in trouble shooting any discrepancies found in the telemetry formats.

9. The RMS Team investigated a clock synchronization problem on the APEX Satellite. The APEX Satellite contains two clocks which were originally planned to be synchronized with GPS every second, however, this caused polling problems with the PASP-Plus experiment. The solution to this problem was to synchronize the clocks once a day and use clock synchronization constants to correct the drift of the vehicle clocks.

3.2 APEX Orbital Data Processing System Task

The sub-section contains a brief description of the APEX functions along with the names of the data items (files and tapes) produced by that function. Detailed information for each function can be found in the APEX requirement and product specifications.

3.2.1 Telemetry Data Processing (TDP) Function

The APEX Telemetry Data Processing System consists of the hardware and software necessary to acquire and analyze the PCM data contained on the analog tapes. The TDP System hardware includes: 1) the VAX 4000-300 Dual-Processor Computer; 2) the 8320 Bit Synchronizer; 3) the Fairchild Weston System 8330 PCM Decommutator; 4) the 8340 Telemetry Expander; 5) the 8350 Digital/Analog Converter; 6) the Sabre Mod 10 Tape Recorder; 7) the Datum Model 9310 Time Code Generator/Translator; and 8) the Time Merge CALCULEX Model CTU-2000.

The APEX TDP System was designed to handle anomalies and perturbations in the acquired telemetry data to ensure that only valid, quality data was provided to user agencies. In addition to standard algorithms for handling common time and frame anomalies, the TDPS Quality Check Program includes algorithms specifically designed for checking and formatting the APEX data.

The APEX QC Program detects and reports anomalies such as sync loss, frame alignment, subframe identifier error, vehicle time code error, and IRIG time anomaly. The quality-checked APEX data files were formatted into major frame aligned records and missing minor frames were filled with a distinct pattern. The APEX TDP System also included programs specifically designed to allow the operator to examine selected portions of the raw or quality-checked data files when anomalies were detected.

The Apex QC Program prints out the APEX Processing Summary at its conclusion. This summary defines the beginning and end of the data for each of the experiments present during the data acquisition. Each experiment's data is identified by the format flag.

The format flags consist of: "0" - Null Data; "13"- Command History; "3" - PASP-Plus Science Data; "4" - Dosimeter Science Data File; "5" - CRUX Science Data; "6" - CRUX SOH Data; "7" - CREDO Science Data; "8" - FERRO Science Data; "9" - FERRO SOH Data; "10" - Stored State of Health; and "11" - Error Log Data.

As with all satellites, the QC software was upgraded after launch to improve data throughput and correct for undocumented changes in satellite software. These corrections and improvements consisted of: 1) changes to the FERRO Data File format; 2) changes to the CRUX SOH data rate; 3) extraction of the Contingency SOH data; and 4) elimination of null filled major frames in the 100% Telemetry Data File.

Removing the null filled major frames eliminated up to 95% of the 100% Telemetry Data File. This reduced the amount of disk space needed to store the 100% Telemetry Data Files and reduced the time required to execute the Telemetry Unpacking Function software.

3.2.2 Ephemeris Computation (EPH) Function

The primary ephemeris quantities, the position and velocity of the satellite, were calculated at arbitrary times by orbital analysis from orbital elements. These elements were themselves calculated from satellite tracking analyses, which provided either the mean characteristics or the instantaneous position and velocity of the satellite at the time the trajectory analysis was carried out.

For APEX these elements were received from DET2, SMC in the position and velocity format with a frequency of approximately once a day. These vectors were quality checked for transmission errors and entered into a sequential state vector data base. Vectors for a specific period were then converted to mean elements averaged over the first two terms in the geopotential expansion and were interpolated to desired times. For APEX, interpolation to integral values of

one-minute intervals gave a data base from which linear interpolation allowed for sufficient accuracy.

Some modifications were made to the CRRES ephemeris software to incorporate features appropriate to the APEX mission. These included the resegmentation of periods from the perigee-to-perigee segmentation of CRRES to the day-to-day segmentation used for APEX. The external magnetic field was abandoned as was appropriate for the low-earth orbit of APEX. Several modifications were made in the field line tracing routines as well, as necessitated by the higher magnetic latitudes and longer field lines encountered by APEX.

3.2.3 Telemetry Unpacking (TUP) Function

The APEX Telemetry Unpacking Function unpacked the 100% Telemetry Data Files created by the Telemetry Data Processing Function and produced time ordered data files for the APEX Experimenters.

The APEX satellite contains three principal experiments. They were the Photovoltaic Array Space Power Plus diagnostics (PASP-Plus), the Cosmic Ray Upset Experiment/Cosmic Ray Environment and Dosimeter (CRUX/CREDO), and the Ferroelectric Memory (FERRO). The Apex ODPS converts the raw telemetry experiment data downlinked from these experiments into computer-compatible APEX Agency Files that are written to APEX Agency Data Tapes (ADTs) that meet the processing/analysis requirements of the APEX Experimenters.

The downlinked major frame consists of 16 minor frames (numbered 0 to 15). Minor frames 0 and 1 contain real time data which was determined at the time that the data was transmitted, and minor frames 2 through 15 contain the recorded data from the satellite's Flight Data Recorder.

The data from the APEX Experiments were written to the APEX Flight Data Recorder (FDR) File(s). The FDR Files were created by the APEX ODPS Telemetry Unpacking Function. The information for the FDR File(s) was obtained from the 100% Telemetry Data File(s) and consisted of agency file and associated data files used to track attitude, error information, etc.

The PASP-Plus experiment data was written to the PASP-Plus Science Data File. Each PASP-Plus physical record contained 30 packets (numbered from 0 to 29), each packet contained 256 bytes. The data rate was one packet per second. If any packets within a PASP-Plus physical record were missing due to telemetry dropout, every bit of the packet was set to "1" ("1"s filled). If a PASP-Plus physical record contained any "1"s filled packets, a dropout flag (an 8 bit word) within the physical record was set to "1", otherwise, the dropout flag was set to "0". If a physical record was completely "1"s filled it was not written to the PASP-Plus Science Data File.

The PASP-Plus Dosimeter is associated with the PASP-Plus experiment. The dosimeter information was written to the Dosimeter Science Data File. This file consisted of a 210 positive integer header record followed by the data records of 840 bytes. The data records consisted of two different modes, normal and housekeeping. In Normal mode, data records were blocked into Dosimeter packet format, ordered from packet "0" to packet "23". In housekeeping mode, data records were blocked into 24 housekeeping packets.

The CRUX experiment data was written to the CRUX Science Data File. The CRUX Science Data File consisted of a 3480 positive integer header record followed by the data records of 13920 bytes. Each CRUX physical record consisted of two 950-byte data packets. To get both packets, the spacecraft Data Management System (DMS) polled CRUX twice in rapid succession every five minutes. Each CRUX Science Data File physical record contained 30 Packets numbered from 0 to 29. CRUX SOH information was written to the CRUX SOH File. The CRUX SOH data consists of 789 bytes which were polled approximately every 12 hours. The data file consisted of a header record followed by one or more data records. Each data record contained the data for a 12 hour period.

The CREDO experiment data was written to the CREDO Science Data File. Each CREDO science data packet consisted of 256 bytes which were polled once every 5 minutes. The data file consisted of a header record followed by a series of data records. Each data record contained CREDO science data from 24 polling periods. Data frames lost to telemetry dropout were reflected by data gaps.

The FERRO experiment data was written to the FERRO Data File. The FERRO Science Data consisted of 780 bytes and was polled once per day. The data file consists of a header record followed by the data records. Each data physical records of the FERRO Science Data File contained 840 bytes consisting of msecs./day, and the 780 byte FERRO science data. FERRO SOH information consisted of 39 bytes which were polled once per minute and written to the FERRO SOH File. The data file consisted of a header record followed by a series of data records. Each data record contained data from 60 polling periods. Downlink data frames lost due to telemetry dropout were reflected by data gaps. The last record of the file may contained "1"s filled frames to keep the record length constant throughout the file.

APEX Spacecraft SOH information was written to the Stored SOH Data File. This information consisted of spacecraft SOH, experiment SOH, attitude information, Global Position System (GPS) information, etc. Each physical record consisted of the msecs./day and the 990 data bytes for each of the 14 downlink minor frames of the Stored SOH downlink major frame.

Error Log information was written to the Error Log File and the real time data contained in minor frames 0 and 1 of each major frame was written to the Real Data File. The error log and real information was saved on disk in the event that a spacecraft anomaly was discovered.

3.2.4 Attitude and Magnetic Field Processing (AMF) Function

The APEX attitude instrumentation consists of a two-axis sun sensor, which measures the sun normal vector, and a magnetometer, which can be used to calculate the roll angle during sunlit periods and estimate the three-axis attitude in eclipse. The attitude control requirements were strictest during sunlit operation, when the sun must be normal to the solar arrays to within one-half degree. This requires the spacecraft x-axis to be collinear with the sun direction to this precision. A less precise requirement was that the dosimeter (spacecraft y-axis) lie in the ecliptic plane to within 5 degrees. There were no set requirements for attitude knowledge, however, knowledge must be sufficient to assess the level of control.

For the APEX satellite, assessment of the degree of control was the primary purpose of attitude computation, since the particle instruments require only the magnetic field, which was measured independently. In sunlight, the two axis sun sensor was used to determine the rotation cone of the satellite around the sun line and the magnetometer measurement was used to find the rotation around this axis. In eclipse, a filter was used to estimate the attitude from a series of magnetometer measurements

In the day-to-day processing of APEX data, the primary tasks were (a) to verify the magnetometer calibrations and (b) to verify the on-board attitude. To do this, the AMF software system performed a post-flight attitude computation. Verification was made by examining the agreement between post-flight and on-board attitude results. Assuming that these were similar, one or the other was passed on to the user in the attitude and magnetic field file. The decision as to whether to pass on the post-flight or the on-board was made depending on which appeared more accurate.

The RMS Team had been active for several years in the development of algorithms and software for on-orbit magnetometer calibration. For the CRRES mission, the methodology employed in these calculations relied on the fact that the spacecraft spun at some constant rate ω around a principal axis. Each sensor signal from a constant external field b appeared as

$$s = g\sin\theta\, b\cos(\phi+\omega t+\phi') + gb\cos\theta + d$$

where θ was the angle that the magnetometer axis makes with the spin axis, b was the projection of the external field onto the spin plane, d was the spin axis component, ϕ the phase of the magnetic field, ϕ' the phase of the magnetometer

sensor, g the gain and d the offset of the magnetometer sensor. The signals were fit to functions of the form

$$s = \alpha\cos\omega t + \beta\sin\omega t + \delta$$

and from the coefficients of the fit, along with the measured orthogonality angles between the sensors, the elevation and relative phase angles, θ and ϕ, were calculated for each sensor. Then the ratios of gains between the sensors were found and two independent spin plane offsets were determined. These were used to find the individual offsets of each sensor with the added knowledge of the spin axis offset Δ.

For APEX, which was non-spinning, a second algorithm was used to determine the offsets along the magnetometer axes and the phase of the instrument in spacecraft coordinates. This software was executed initially to give gains and offsets for use in processing the magnetometer data and was used from time to time to verify that the situation has not changed significantly. Also, should examination of the data show relatively large offsets induced by spacecraft events, modifications were included in the processing system to compensate for these offsets, providing that they were identified and attributed to specific on-board events.

3.2.5 Agency Tape Generation (ATG) Function

The Agency Tape Generation Function created the APEX Agency Data Tapes (ADTs) that were sent to the agencies. The APEX ADTs were created for the CRUX, CREDO and FERRO agencies on floppy disks by an IBM compatible PC from files stored on the VAX 4000 computer disks. The PASP-Plus data were not written to ADTs.

The Agency Data Tapes consisted of the Flight Data Recorder File(s) and the support files accumulated during a set period (i.e. nine days).

Only those APEX Periods with a complete set of data files (as indicated in the Status File) were copied to tape and three of APEX Periods were copied to each Agency Data Tape.

The following files were written to the CREDO ADT in the following order: 1) the Ephemeris File; 2) the Attitude and Magnetic Field File; 3) the Command History File; and 4) the CREDO Science Data File.

The following files were written to the CRUX ADT in the following order: 1) the Ephemeris File; 2) the Attitude and Magnetic Field File; 3) the Command History File; 4) the CRUX SOH Data File; and 5) CRUX Science Data File.

The following files were written to the FERRO ADT in the following order: 1) the Ephemeris File; 2) the Attitude and Magnetic Field File; 3) the Command History File; 4) the FERRO SOH Data File; and 5) the FERRO Science Data File.

The files for the PASP-Plus experiment were processed while on the VAX 4000 disk. They consist of: 1) the Ephemeris File; 2) the Attitude and Magnetic Field File; 3) the Command History File; 4) the PASP-Plus Data File; and 5) the Dosimeter Data File.

The Ephemeris File is created by the ATG Function and is composed of a header record followed by the data extracted from the data records of the Orbital Data File. The data records of the Ephemeris File contain the ephemeris data from the Orbital Data File for the period converted into an integer format.

The header record contains orbit identification information, valid time span information, times of first ascending node crossing and first perigee, eclipse and maximum observation times. The first set of ephemeris corresponds to 0 seconds UT on the day of interest. The last set corresponds to 1800 seconds UT on the following day. This is represented in the data stream by times greater than 86,400 seconds. The frequency is once per minute at integral minutes.

The Attitude and Magnetic Field (AMF) File is created by the Attitude and Magnetic Field Processing Function and is composed of values of the computed pitch, roll, and yaw angles and of the calibrated measured magnetic field.

The AMF File contains the vehicle attitude and magnetometer data generated at one-minute intervals. The file consists of a header record followed by a series of data records. Each data record contains up to 60 data sets. The data is in the form of 32-bit positive integers (i.e. 31 data bits with the most significant bit set equal to zero). Bias and offset values are provided to allow conversion of the integer data to engineering units. Gaps are present whenever there are telemetry dropouts. The last record of any file may contain "1"s filled frames, since the data sets are unlikely to end on a boundary of 60.

The Command History File consists of a 270 positive integer header record followed by the data records of 1080 bytes. Each data record contains up to 120 APEX time-tagged, executed commands. Each command is 11 bytes long and consists of the spacecraft 4-byte time tag (command execution time) followed by 7 bytes of command identification data. Portions of data records which are unused due to an insufficient number of commands are "1"s filled. Each 11-byte command packet is structured as follows:

The PASP-Plus Science Data File consists of a 1950 positive integer header record followed by the data records of 7800 bytes. The data records contain the information from the PASP-Plus experiment (GL-803). Each PASP-Plus physical record contains 30 packets, each packet contains 256 bytes. The data rate is one packet per second. Packets missing within downlink major frames (due to telemetry dropout) are "1"s filled. If a physical record is completely "1"s filled it will not be written to the PASP-Plus Science Data File. An 8 bit dropout flag within the PASP-Plus physical record is set to "1" if any packet is "1"s filled, otherwise, the dropout flag is set to "0". Each physical record contains 30 Packets numbered from 0 to 29.

The Dosimeter Science Data File contains the two types of physical records from the APEX Dosimeter Experiment. One is for the normal mode, and the second is for housekeeping mode. There are 24 packets in each "normal" and "housekeeping" physical record. Each packets consists of 34 bytes. The most significant bit (MSB) of the Dosimeter packet ID word is set to "1" when the Dosimeter is in Housekeeping mode. In Normal mode, data records are blocked into Dosimeter packet format, ordered from packet "0" to packet "23". In housekeeping mode, data records are blocked into 24 housekeeping packets.

The CREDO Science Data File consists of a 1560 positive integer header record followed by the data records of 6240 bytes. Each CREDO science data consists of 256 bytes which are polled once every 5 minutes. The data file consists of a header record followed by a series of data records. Each data record contains CREDO science data from 24 polling periods. Data frames lost to telemetry dropout are reflected by data gaps. The last record of the file may contain "1"s filled frames to keep the record length constant.

The CRUX Science Data File consists of a 3480 positive integer header record followed by the data records of 13920 bytes. Each CRUX physical record consists of two 950-byte data packets. To get both packets, the spacecraft DMS polls CRUX twice in rapid succession every five minutes. The spacecraft each packet contains 256 bytes. The data rate is one packet per second. Packets missing within downlink major frames (due to telemetry dropout) are "1"s filled. If a physical record is completely "1"s filled it will not be written to the CRUX Science Data File. An 8 bit dropout flag within the CRUX physical record is set to "1" if any packet is "1"s filled, otherwise, the dropout flag is set to "0". Each physical record contains 30 Packets numbered from 0 to 29.

The CRUX SOH Data File consists of a 210 positive integer header record followed by the data records of 840 bytes. The CRUX SOH data consists of 789 bytes which are polled approximately every 5 minutes. The data file consists of a header record followed by one or more data records. Each data record contains the data for a 5 minute period.

The FERRO Science Data File consists of a 210 positive integer header record followed by the data records of 840 bytes. The FERRO Science Data consists of 780 bytes and is polled once per day. The data file consists of a header record followed by two data record. Each data records are separated by 24 hours. The remainder of the file is "1" filled.

The FERRO SOH Data File consists of a 660 positive integer header record followed by the data records of 2640 bytes. The FERRO State of Health data consists of 39 bytes which are polled once per minute. The data file consists of a header record followed by a series of data records. Each data record contains data from 60 polling periods. Downlink data frames lost due to telemetry dropout are reflected by data gaps. The last record of the file may contain "1"s filled frames to keep the record length constant throughout the file.

3.2.6 Data Flow Control (DFC) Function

The Data Flow Control Function software managed the processing of large volumes of flight telemetry data throughout the APEX ODPS.

In order to manage these processes, this function maintained and/or updated the following information: 1) state vectors; 2) clock correlation information; 3) APEX Period Definition information; 4) digital tape, (A)RTS Tape (analog tape) information; and 5) APEX Period status information. This information was combined to produce a time history of the major activities and progress in generating Agency Data Tapes for the APEX mission.

Along with managing and controlling the APEX ODPS, this function also created the Initialize Files and the Execution Files for the Telemetry Unpacking (TUP) Function, the Ephemeris Computation (EPH) Function, the Agency Tape Generation (ATG) Function, and the Attitude and Magnetic Field Processing (AMF) Function.

3.3 APEX ODPS Processing Summary

The APEX Satellite was launched on 3 August 1994 and was delivering excellent quality data at the end of this contract.

The following summary includes the APEX information through September 30, 1995.

- 99 Analog data tapes were processed.
- 15 APEX Periods were created.
- 2 Agency Data Bulletins were mailed out listing the APEX Periods included in the ADTs and any problems encountered during the periods.

3.3.1 APEX ODPS Processing Summary Comments

There were undocumented changes made to data sampling rates by the APEX Satellite DMS. These changes were discovered by PL/GPD after the flight data started to arrive.

4.0 MSTI-2 DATA PROCESSING SYSTEM TASK

4.1 Overview

This section contains a brief overview of the second Miniature Sensor Technology Integration Satellite (MSTI-2) ODPS. Each of the following paragraphs in this section describes a different MSTI-2 ODPS Function. Figure 4.-1 contains the functional flow diagram for the MSTI-2 ODPS.

The primary objectives of the MSTI-2 satellite mission were to: 1) demonstrate missile tracking and earth observation; 2) demonstrate miniaturized sensor technologies for the Short Wave InfraRed (SWIR) Camera and the Medium Wave InfraRed (MWIR) Camera; 3) launch detection and boost phase tracking; and 4) support environmental monitoring approaches. In order to obtain these objectives the MSTI-2 Satellite downlinked the SWIR and MWIR camera images along with payload and spacecraft data on a 1.0 Mbps telemetry data stream. Additional spacecraft real-time and stored data was downlinked on a low rate (32 Kbps) telemetry data stream.

The MSTI-2 space probe data was processed at PL/GPD using the PL/GPD Orbital Data Processing System (ODPS) to create the Agency Files and Agency Data Tapes (ADTs) that were distributed to the various agencies. The ODPS was divided into six functions. These six functions were:

1) Telemetry Data Processing (TDP)
2) Ephemeris Computation (EPH)
3) Telemetry Unpacking (TUP)
4) Attitude Processing (ATT)
5) Agency Data Tape Generation (ATG)
6) Data Flow Control (DFC)

The MSTI-2 Satellite ODPS was the second successful modification of the CRRES ODPS documentation and software. The MSTI-2 documentation and software consisted of: 1) the requirement specifications for each MSTI-2 function; 2) the product specifications for each MSTI-2 function; and 3) the software for each MSTI-2 function. The MSTI-2 software was successfully

tested using simulated MSTI-2 data and MSTI-2 test data created during the MSTI-2 Compatibility Tests performed at Vandenburg AFB before launch.

Orbital elements were provided periodically by DET 2, SMC and were used to create a time history of the satellite's ephemerides.

As in the case of CRRES and APEX, the input telemetry data was recorded on IRIG standard magnetic tapes (analog tapes) at the (A)RTS stations. The PCM telemetry data stream was decommutated, quality checked, edited and merged with IRIG UT code, and formatted into 100% Telemetry Data Files on disk. The 100% Telemetry Data Files were archived on 8mm EXABYTE tapes in the event that reprocessing was necessary.

In addition, the MSTI-2 telemetry data was also relayed by satellite to DET 2, SMC in an attempt to speed up processing. However, a comparison of the data quality of the analog tapes recorded at the remote tracking stations and those relayed to DET 2, SMC, showed that the relayed data was of 6 to 12% poorer quality.

The MSTI-2 Satellite was in operation from May 8 to September 5, 1994. During this time, there were 985 analog tapes received at PL/GPD. Of these tapes, 306 were relayed to DET 2, SMC. The remaining were recorded at the (A)RTS stations.

The Erasable Disk Memory of the MSTI-2 Satellite (EDMM) was divided into segments. As an MSTI-2 event, as defined in the Erasable Disk Mass Memory (EDMM) Log, was recorded by MSTI-2 Satellite, the data was stored in one or more of these segments. The MSTI-2 Period was defined as the data in a single segment. At the appropriate time, the data for a single segment (MSTI-2 Period) was telemetered from the satellite to an (A)RTS station which in turn was mailed to Phillips Laboratory, Data Analysis Division (PL/GPD). Only when all of the analog tapes for a complete event were received at PL/GPD, was the data for that event processed. Because of the location of the (A)RTS stations, it could take up to 30 days for all of the analog tapes for a single event to arrive at PL/GPD.

Attitude sensing elements on board the spacecraft provided sun angle, earth horizon crossings, and gimbal angles. These time correlated inputs were used to determine vehicle attitude versus time.

The data for a single analog tape (a MSTI-2 Period) was extracted from a 100% Telemetry Data File, time correlated and packed into Agency Files. These Agency Files were combined with the ephemeris and attitude data files to create the 8mm EXABYTE Agency Data Tapes (ADTs) distributed to the experimenters. Only complete events containing one or more MSTI-2 Periods were written to the ATDs. There were 204 ADTs created for MSTI-2.

The ODPS analytic routines to perform these tasks were previously designed, developed and implemented for the CRRES Project. Figure 4 graphically illustrate the functional relationships of these analytic routines. This figure will be referenced throughout this document.

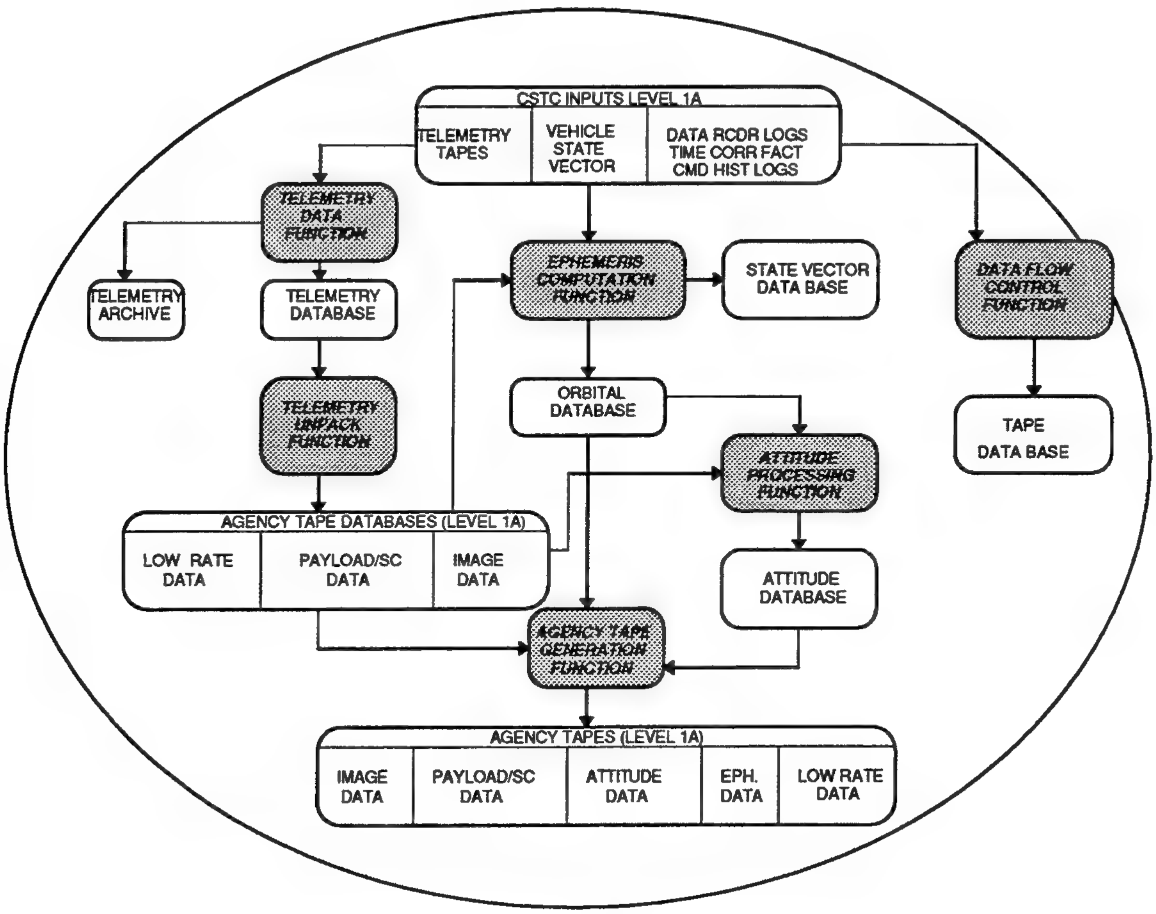

FIGURE 4 MSTI-2 ODPS FUNCTIONAL FLOW

4.2 MSTI-2 Orbital Data Processing System Functions

This sub-section contains a brief description of the MSTI-2 functions along with the names of the data items (files and tapes) produced by that function. Detailed information for each function can be found in the MSTI-2 requirement and product specifications.

4.2.1 Telemetry Data Processing (TDP) Function

The MSTI-2 TDP System consists of the same hardware used to acquire and analyze the PCM data contained on the analog tapes for the APEX Satellite. The TDP System hardware included: 1) the VAX 4000-300 Dual-Processor Computer; 2) the Fairchild Weston System 8330 PCM Decommutator; 3) the 8320 Bit Synchronizer; 4) the 8340 Telemetry Expander; 5) and the 8350 Digital/Analog Converter.

The MSTI-2 TDP System was designed to handle anomalies and perturbations in the acquired telemetry data to ensure that only valid, quality data was provided to user agencies. In addition to standard algorithms for handling common time and frame anomalies, the TDPS Quality Check Program included algorithms specifically designed for checking and formatting the MSTI-2 data. The MSTI-2 QC Program detected and reported anomalies such as sync loss, frame misalignment, subframe identifier error, vehicle time code error, and IRIG time anomaly. The quality-checked MSTI-2 data files were formatted into major frame aligned records and missing minor frames were filled with a distinct pattern. The MSTI-2 TDP System also included programs specifically designed to allow the operator to examine selected portions of the raw or quality-checked data files when anomalies were detected.

As the actual MSTI-2 data was being processed, the data was reviewed by Phillips Laboratory personnel in order to make improvements of the current capabilities in the telemetry data processing hardware and software. The major improvements consisted of:

1) The coaxial cables were shortened and terminated with their characteristic impedance to reduce ringing and provide more precise data to clock alignments.

2) The "Automatic Data Detect and Invert" feature of the PCM Decommunication Unit was eliminated to prevent improper data inversion due to synchronization word misinterpretation following data dropout.

3) The tape speed was cut in half to reduce tape recorder generated noise and allow for a more precise alignment of playback tape recorder heads.

4) The clock values extracted from the EDMM Log were used as actual start and stop times to eliminate the acquisition of extraneous images.

4.2.2 Ephemeris Computation (EPH) Function

The MSTI-2 Ephemeris Computation Software calculated ephemeris at arbitrary points as determined from reading the times of the images from the engineering file. Ephemeris was added for the moon, since observation of the moon was carried out during the mission. The MSTI-2 Ephemeris also provided the input for the computation of attitude associated properties, describing the look direction of the telescope.

The objective of the ephemeris generation was to provide users with a comprehensive data base of uniform accuracy and which contained sufficient parameters so that most secondary data analyses was carried out without reference to software models of any kind. In order to assure accuracy, careful quality control was necessary throughout the mission. The first step in quality control was the examination of the state vectors for self-consistency and to ensure that orbital adjustments have not been made. After generation of the ephemeris, the completed files were re-read and a plot was made which subjects the ephemeris quantities to several tests for reasonableness.

The actual Ephemeris processing for the MSTI-2 Satellite began by obtaining the vehicle state vectors electronically or via FAX from DET 2, SMC. The state vectors were then quality checked and entered into the State Vector Library File. For each MSTI-2 Period, a program was executed to read the GMT of the image and store it in a temporary file. A second Ephemeris Program was executed to produce the state vectors and solar/lunar models for each image time.

4.2.3 Telemetry Unpacking (TUP) Function

The Telemetry Unpacking Function unpacked the (High and Low) Rate 100% Telemetry Data Files created by the Telemetry Data Processing Function and produced time ordered data files for the MSTI-2 Experimenters.

When an event was recorded by the MSTI-2 Satellite, the image data (high rate data) was stored on the satellite's memory to be down-loaded to the (A)RTS stations at a rate of 1 megabit per second when an (A)RTS station was available. As each image data file was down-loaded to the (A)RTS station, real-time data (low rate data) was also down-loaded at a rate of 32

kilobits per second. The low rate file may have also included vehicle state of health data stored on the satellite's memory.

If the MSTI-2 Satellite was in range of an (A)RTS station while it was recording an event, real-time data may also have been recorded at the (A)RTS station. In this case, the real-time 100% Telemetry Data File was unpacked by the TUP Function to be included with the image files.

As the (A)RTS tapes for a MSTI-2 event arrived at PL/GPD, they were decommutated and quality checked, and the resultant data recorder acquisitions were written to 100% Telemetry Data Files. One 100% Telemetry Data File was made for each (A)RTS analog tape.

As each 100% Telemetry Data File became available, the Telemetry Unpacking Program time correlated and unpacked the 100% Telemetry Data File into Image Data Agency Files. If low rate data was recorded on the ground when the event was being recorded by the satellite, the 100% Telemetry Data File that contained the low rate data was time correlated and unpacked into the Low Rate Data File.

The Image Data Agency File contained the MWIR and SWIR data in the same chronological order as it was downlinked from the spacecraft. Each major frame also includes the spacecraft time of the image (year, day and msecs./day computed from the MSTI-2 Mission Time (MMT) which was received in 10s of milliseconds), identifying flags, spacecraft data, and payload data.

The Low Rate Data File contained the data extracted from the 32 Kbps data stream. Each record of the Low Rate Data File consisted of 416 bytes containing the time associated with the record (year, day and milliseconds of the day) calculated from the MMT and 390 data bytes.

As each image of the high rate data was unpacked, the payload data and the spacecraft data contained in minor frames 252 and 253, respectively, was written to the Engineering Data File. The Engineering Data File was used by the Attitude Processing Function to create the Attitude File.

4.2.4 Attitude Processing (ATT) Function

The production of attitude files for the MSTI-2 Satellite required processing of the on-board attitude sensor measurements and the on-board computed attitude. This data was then used to generated an attitude model. The sensor data and final form of the attitude information varies greatly from satellite to satellite and the design of the attitude processing system must take into account the unique mission requirements of each satellite and payload.

The attitude instruments for the MSTI-2 satellite included a two-axis sun sensor and a rotating horizon sensor. The on-board attitude was continuously analyzed and a post-flight attitude was computed as well. The on-board attitude and post-flight attitude data was written to the Attitude File for distribution to the experimenters.

Also included in the Attitude File were several derived quantities that described the pointing direction of the telescope. These quantities were provided for the convenience of the users of the image data.

A major task at the outset was the verification of the calculated attitude and of the derived quantities through comparison of recorded images with expected physical objects, such as stars and coastlines. A secondary task was the investigation of improvements that might be made to the post-flight attitude in order to improve accuracy.

The actual processing of the Attitude Function consisted of the execution of an initial attitude program that read the payload and spacecraft data from the Engineering File. This program extracted the attitude data and the gimbal angles. A second attitude program was executed which calculated the post-flight attitude and telescope look directions, and interpolated these to the times of each image.

4.2.5 Agency Tape Generation (ATG) Function

The Agency Tape Generation Function created the MSTI-2 Agency Data Tapes (ADTs) that were sent to the agencies.

The MSTI-2 ADTs for all experimenters consisted of 8mm EXABYTE magnetic tapes, and contained only those MSTI-2 Periods with a complete set of data files.

The files for each MSTI-2 Period written to the Agency Data Tapes included: 1) the Ephemeris File; 2) the Attitude File; 3) the Image Data Agency Files; 4) the Engineering Data File; and 5) the Low Rate Data File (32 Kilobit). These files were written in 32-bit integer format in the order listed above.

The Ephemeris File was created by the Ephemeris Computation Program and contains a header record followed by the data records (converted from 64-bit floating point to 32-bit integer) of the Orbital Data File. The data records of the Orbital Data File contain the ephemeris database for the MSTI-2 period.

Each record in the Ephemeris File contained information for a time identical to the sequential record in the Engineering Data File. The parameters include: 1) space-craft position and velocity in the ECI coordinate system; 2) satellite altitude, latitude and longitude in the geocentric coordinate system; 3) solar zenith and elevation angles; 4) the position in ECI of the sun and moon; and 5) the right ascension of Greenwich. All quantities were referenced to the True-of-Date ECI system.

The Attitude File was created by the Attitude Processing Function. This file consisted of time tagged attitude data computed by the on-board system and post flight attitude computed during Attitude Data Processing. This file also contained the reported gimbal angles. There was one time-tagged record in the Attitude File for each record in the Engineering Data File.

On-board and post-flight attitude was computed each 200 ms. Attitude points were interpolated linearly between the times at which the attitude was computed. Gimbal angles corresponded to those measured for a particular image, with interpolation being carried out when necessary. Mode flags and other discrete data items corresponded to the last value encountered.

The Image Data Agency File contains the MWIR and SWIR data in the same chronological order as it was downlinked from the spacecraft. Each major frame also includes the spacecraft time of the image (year, day and UT computed from the MMT in milliseconds), identifying flags, spacecraft data, and payload data.

The data in the Engineering Data File was extracted from the Engineering Record associated with each camera image. The payload data was taken from line 252 of the major frame and the spacecraft data was taken from line 253 of the major frame.

The data in the Low Rate Data File was extracted from the 32 kb data stream. Each record consisted of 416 bytes. The time was computed from the MMT contained in the real time portion of the telemetry frame. The low rate data consisted of payload, software, and hardware telemetry parameters.

4.2.6 Data Flow Control (DFC) Function

The Data Flow Control Function software managed the processing of large volumes of flight telemetry data throughout the MSTI-2 ODPS.

In order to manage these tapes, this function maintained and/or updated the following information: 1) state vectors; 2) clock correlation information; 3) MSTI-2 Period Definition information; 4) digital tape, (A)RTS Tape (analog

tape) information; and 5) MSTI-2 Period status information. This information was combined to produce a time history of the major activities and progress in generating Agency Data Tapes for the MSTI-2 mission.

Along with managing and controlling the MSTI-2 ODPS, this function also created the Initialize Files and the Execution Files for the Telemetry Unpacking (TUP) Function, the Ephemeris Computation (EPH) Function, the Agency Tape Generation (ATG) Function, and the Attitude Processing (ATT) Function.

The major operations controlled by the Data Flow Control Function included:

a) Displayed state vector data.

b) Updated and displayed clock correlation information.

c) Displayed MSTI-2 Period Definition information.

d) Updated and displayed (A)RTS Tape data.

e) Updated and displayed MSTI-2 Period status information.

f) Created and displayed the Log File.

g) Updated and displayed Agency Data Tape information.

h) Created the necessary initialize files and execution files for the execution of the TUP Function, the EPH Function, the ATT Function and the ATG Function.

4.3 MSTI-2 Processing Summary

The MSTI-2 Satellite was launched on 8 May 1994 and was delivering quality data until it became non-responsive on 5 September 1994. The following summary includes these dates.

985	Analog data tapes were received and logged
306	Analog data tapes contained data relayed through DET 2, SMC.
204	Agency Data Tapes were created.
22	Agency Data Bulletins were mailed out describing the data and the quality of the data recorded.

4.3.1 MSTI-2 Processing Summary Comments

The decryption keys for use in the KGR62 box to support the MSTI-2 mission arrived and were installed on 22 March 1994. PL/GPD received the first encrypted MSTI-2 test tape from Edward's Air Force Base on 30 March 1994. This data was generated using a data simulator not from the actual payload.

The first data tape with encrypted payload data was received on 21 April 1994. A copy of the MSTI-2 Compatibility Test Tape was received on 5 May 1994 just 3 days prior to launch.

The first flight data tapes arrived at PL/GPD on 13 May 1994. They contained Low Rate Data only.

Shipment to PL/GPD of (A)RTS Station tapes was being held up early in the mission hoping that the data received by relay satellite would be of acceptable quality. As the relay data tapes that contained image data began arriving, it was discovered that the data quality was outside required limits.

Data quality comparisons between the (A)RTS station tapes and those tapes relayed through DET 2, SMC indicated a 6 - 12 % differential in favor of the (A)RTS Station tapes. Because of the lesser quality of the relay tapes, the decision was made to use (A)RTS Station tapes whenever possible to obtain the highest data quality possible and a request was made to deliver all MSTI-2 (A)RTS station tapes to PL/GPD. When an (A)RTS station tape displayed a lower quality then the relay tape was used.

The first (A)RTS station tapes arrived on 13 June 1994. They were from orbits 2 - 17 and contained Low Rate Data only.

The first (A)RTS station tapes containing image data were received from TCS Rev 103.4 on 15 June 1994.

The first MWIR Functionality test data from HTS Rev 110.4 was received on 13 June 1994.

The first Agency Data Tapes were issued 17 June 1994

The first Peacekeeper Event produced no useable images.

Data tapes were shipped to PL/GPD from DET 2, SMC for Revs. 472 to 485 which should have contained Minute Man III images. All of these tapes which were recorded at DET 2, SMC contained no high rate data. No Minute Man III data images were available from these tapes. PL/GPD personnel contacted Det 2 SMC personnel regarding the problem. They reported

operational problems in the Wide Band Recording site at DET 2, SCM caused the loss of data.

The MSTI-2 Chief Systems Engineer was on site from June 6 to June 10 1994. PL/GPD personnel provided attitude and tracking data in great detail. PL/GPD personnel helped analyze the image and engineering data to better understand the operation of the camera.

PL/GPD personnel worked weekends to support MSTI-2 payload engineers to provide them with much finer spacecraft engineering data to assist them in determining gyro functionality. PL/GPD personnel also provided additional spacecraft systems engineering data in the preparation of tracking the Sergeant vehicle launched from Wallops Island.

PL/GPD personnel responded to spacecraft operational changes which apparently interlaced the image data differently than that being done previously. We modified the Telemetry Unpacking routines in response to these changes. These changes were verified by MRC and ISI.

PL/GPD personnel provided calibrated strip chart recordings of the AGC during the last data pass. We provided calibrated strip chart recordings of AGC during "normal" payload shut down when accomplished by normal commands for comparison purposes

5.0 ADDITIONAL SPACE PROBES

In addition to the CRRES, APEX and MSTI satellites, the telemetry data for additional space probes was acquired and Quality Checked.

The high altitude balloons include: 1) Atmospheric Backscatter Lidar Experiment (ABLE); and 2) Stratospheric Cryogenic Interferometer Balloon Experiment (SCRIBE).

The rocket payloads include: 1) Light ExoAtmospheric Probe (LEAP); 2) Beam Energy Accelerator Return (BEAR); 3) SPectral Infrared Rocket Interferometer Telescope (SPIRIT); 4) Survey Probe Infrared Celestial Experiment (SPICE); 5) Far InfraRed Sky Survey Experiment (FIRSSE); 6) Space Power Experiments Aboard Rockets (SPEAR); and 7) EXCited Electron Deposition (EXCEDE).

The Space Shuttle Payloads (STS-39) include: 1) Infrared Background Signature Survey (IBSS); and 2) Cryogenic Infrared Research Instrument for Shuttle (CIRRIS).

Data was extracted from analog instrumentation tapes, digitized and transferred to 9 track digital tapes for a special project group at Lincoln Laboratories. A letter of commendation was received by Mr. Alan Griffin PL/GPD for this support on June 20,1991.

6.0 LESSIONS LEARNED AND RECOMMENDATIONS

6.1 Lesson Learned: Failure to use IRIG Standard

The selection of a non IRIG Frame Synchronization Pattern for the MSTI-2 payload caused unnecessary loss of data. IRIG recommends specific bit patterns for each required frame synchronization word length. These patterns have been chosen to provide the smallest total probability of false synchronization.

The use of FFOOFF or FFOOFE as the frame synchronization pattern for MSTI-2 provided a much higher probability of false synchronization. The FF or 00 patterns occurred quite frequently in the data stream. With a very stable clock, no noise and tight adjustment of frame synchronization word location (window) a minimum of false frame synchronizations occur. Once you have and interruption in the serial bit stream, resynchronization becomes more uncertain when using non IRIG pattern (pattern least likely to occur randomly)

When searching the serial bit stream for the proper programmed frame synchronization pattern (FF 00 FF) the serial bit stream enters the 24 bit frame synchronization pattern comparitor (advancing 1 bit each bit clock period) until either 0 errors (exact match) or 24 errors (inverted match) was detected. If 0 errors were detected, the frame synchronization window closes, the comparitor counts the correct (preprogrammed) number of bit periods in a minor frame, and then begins the comparison again. If 0 errors were detected again in the correct location, the data synchronization was confirmed and data was transferred out. If 24 errors were detected, it was assumed that the frame synchronization pattern was inverted, the comparitor rechecks for frame synchronization in the proper location again and transfers the inverted data out. When processing the MSTI-2 data this detect and invert feature had to be disabled.

In the case of MSTI-2, the 24 bit comparitor detected both 0 errors and/or 24 bit errors in the improper locations, thus transferring improper data out. By using a unique frame synchronization pattern, the probability of these problems occurring would be very small. Each time that the proper frame synchronization verification was lost, data was lost.

6.1.1 Recommendation

Use IRIG Standards when designing airborne telemetry systems whenever possible.

6.2 Lesson Learned: Single Event Upsets

Single Event Upsets are unpredictable and occur when the vehicle is exposed to unfriendly environments. The primary example was the spacecraft clock upsets on the CRRES Satellite.

6.2.1 Recommendation

Single event upsets in spacecraft systems should be anticipated if predicted ephemerides indicate exposure to unfriendly environment. If the vehicle is expected to be an unfriendly environment, the proper shielding should be provided or the selection of parts altered.

6.3 Lesson Learned: Invalid/Incomplete Data Samples

Invalid and/or incomplete data samples provided to PL/GPD have caused a delay in data processing due to incompatibilities not disclosed prior to launch.

In the case of MSTI-2, the data samples were simulated and were not a true representation of flight data. When the MSTI-2 (A)RTS tapes arrived at PL/GPD, they contained portions of data dumped from buffers prior to the actual data segment which were not demonstrated in the simulated data. This data was invalid and caused loss of synchronization lock.

The MSTI-2 vehicle time code was not available in all low rate (32 Kbps) data. The time code was only available in "real time" acquisitions.

The APEX data formats were changed just prior to launch. PL/GPD were not informed of these changes and the time required to determine what changes were made and correct the data processing software caused a delay in the distribution of the APEX agency files and tapes.

The CRRES flight data contained a 10 second drop out while the flight data recorder changed tracks and reversed direction. This was never present in the ground recorded data.

6.3.1 Recommendation

Data processing personnel and resources should be included in the spacecraft testing program to collect valid data and anticipate possible

problems. All sample data should be complete as possible and PL/GPD should be kept up to date when any last minute changes are made.

6.4 Lesson Learned: Quick Look Ground Support Equipment

Ground Support Equipment (GSE) does not provide the payload engineers with data in sufficient detail. Quick look data is just that, it is not intended to be a complete data processing facility.

6.4.1 Recommendation

Payload engineers who need greater definition in their data could be on site at the complete data processing facility and be able to obtain more than just samples of the raw data. Both manpower (orbital analysts, program software analysts, and telemetry engineers) and equipment resources would be available.

7.0 ACRONYMS

ABLE	Atmospheric Backscatter Lidar Experiment
ACQ	Acquired
ADT	Agency Data Tape
AMF	Attitude and Magnetic Field Processing
APEX	Advanced Photovoltaic and Electronics Experiment
(A)RTS	(Automated) Remote Tracking Station
ATG	Agency Tape Generation
ATT	Attitude Processing
BEAR	Beam Energy Accelerator Return
CDR	Critical Design Review
CIRRIS	Cryogenic Infrared Research Instrument for Shuttle
CRRES	Combined Radiation and Release Effects Satellite
CREDO	Cosmic Ray Environment and Dosimeter
CRUX	Cosmic Ray Upset Experiment
CSTC	Consolidated Satellite Test Center
COTR	Contracting Officers Technical Representative
DET 2 SMC	Space and Missile Systems Center, Detachment 2
DFC	Data Flow Control Function
DMS	Data Management System
EDMM	Erasable Disk Mass Memory
EPH	Ephemeris Computation
EXCEDE	EXCited Electron Deposition
FERRO	Ferroelectric
FDR	Flight Data Recorder
FIRSSE	Far InfraRed Sky Survey Experiment

FM	Frequency Modulated
GTO	Geosynchronous Transfer Orbit
GSE	Ground Support Equipment
IBSS	Infrared Background Signature Survey
IRIG	Inter Range Instrumentation Group
ISI	Integrated Systems Inc.
LASSII	Low Altitude Satellite Studies of Ionospheric Irregularities
LEAP	Light ExoAtmospheric Probe (LEAP); 2)
MFF	Major Frame Format
MMT	MSTI Mission Time
MSTI-2	Second Miniature Sensor Technology Integration Satellite
MSTI-3	Third Miniature Sensor Technology Integration Satellite
MWIR	Medium Wave InfraRed
NRZL	Non Return Zero Level
ODPS	Orbital Data Processing System
OSC	Orbital Sciences Corporation
PAM	Pulse Amplitude Modulated
PCM	Pulse Code Modulation
PDR	Preliminary Design Review
PL/GPD	Phillips Laboratory/Data Analysis Division
QC	Quality Checked
SCRIBE	Stratospheric Cryogenic Interferometer Balloon Experiment
SGLS	Space-Ground-Link Subsystem
SOH	State of Health
SPEAR	Space Power Experiments Aboard Rockets
SPICE	Survey Probe Infrared Celestial Experiment
SPIRIT	SPectral Infrared Rocket Interferometer
SWIR	Short Wave InfraRed
TDP	Telemetry Data Processing
TDPS	Telemetry Data Processing System
TUP	Telemetry Unpacking
UT	Universal Time

APPENDIX 1 LIST OF DELIVERED DOCUMENTS

The following list of documents were delivered for the CRRES, APEX and MSTI-2 programs. The list of the required CRRES documents is contained in the final report for the CRRES Project (see the first reference)

PL-TR-91-2303	"Final Report for the CRRES Orbital Data Processing Task" Phillips Laboratory, Data Analysis Division, Hanscom AFB, December 20,1990. ADA234286
APEX-DMP	"Preliminary Data Management Plan for the APEX Orbital Data Processing System", Phillips Laboratory, Data Analysis Division, February 24,1992.
APEX-AMP-01	"Software Requirements Specification for the APEX Orbital Data Processing System Attitude and Magnetic Field Processing Function", Radex, Inc., December 10, 1991.
APEX-AMP-02	"Software Detailed Design Document for the APEX Orbital Data Processing System Attitude and Magnetic Field Processing Function", Radex, Inc., April 20, 1992.
APEX-AMP-06	"Software Test Procedure for the APEX Orbital Data Processing System Attitude and Magnetic Field Processing Function", Radex, Inc., November 16, 1992.
APEX-AMP-07	"Software Test Report for the APEX Orbital Data Processing System Attitude and Magnetic Field Processing Function", Radex, Inc., February 8, 1993.
APEX-ATG-01	"Software Requirements Specification for the APEX Orbital Data Processing System Agency Tape Generation Function", RMS Technologies, Inc., December 10, 1991.
APEX-ATG-02	"Software Detailed Design Document for the APEX Orbital Data Processing System Agency Tape Generation Function", RMS Technologies, Inc., April 20, 1992.
APEX-ATG-03	"Software Product Specification for the APEX Orbital Data Processing System Agency Tape Generation Function", RMS Technologies, Inc., August 3, 1993.

APEX-ATG-04 "Software User's Manual for the APEX Orbital Data Processing System Agency Tape Generation Function", RMS Technologies, Inc., December 1, 1992.

APEX-ATG-06 "Software Test Procedure for the APEX Orbital Data Processing System Agency Tape Generation Function", RMS Technologies, Inc., May 5, 1992.

APEX-ATG-08 "APEX Agency Tape Generation Function, Code Listing Notebook", RMS Technologies, Inc., August 7, 1992.

APEX-DFC-01 "Software Requirements Specification for the APEX Orbital Data Processing System Data Flow Control Function", RMS Technologies, Inc., December 10, 1991.

APEX-DFC-02 "Software Detail Design Document for the APEX Orbital Data Processing System Data Flow Control Function", RMS Technologies, Inc., April 20, 1992.

APEX-DFC-03 "Software Product Specification for the APEX Orbital Data Processing System Data Flow Control Function", RMS Technologies, Inc., August 3, 1993.

APEX-DFC-04 "Software User's Manual for the APEX Orbital Data Processing System Data Flow Control Function", RMS Technologies, Inc., December 1, 1992.

APEX-DFC-06 "Software Test Procedure for the APEX Orbital Data Processing System Data Flow Control Function", RMS Technologies, Inc., May 5, 1992.

APEX-DFC-07 "Software Test Report for the APEX Orbital Data Processing System Data Flow Control Function", RMS Technologies, Inc., December 17, 1992.

APEX-DFC-08 "APEX Data Flow Control Function, Code Listing Notebook", RMS Technologies, Inc., August 7, 1992.

APEX-EPH-01 "Software Requirements Specification for the APEX Orbital Data Processing System Ephemeris Computation Function", Radex,Inc. December 2,1991.

APEX-EPH-02 "Software Detail Design Document for the APEX Orbital Data Processing System Ephemeris Computation Function", Radex,Inc. April 21, 1992.

APEX-EPH-04	"Software User's Manual for the APEX Orbital Data Processing System Ephemeris Computation Function", Radex,Inc. July 1, 1993.
APEX-EPH-06	"Software Test Procedure for the APEX Orbital Data Processing System Ephemeris Computation Function", Radex,Inc. Nov 16, 1992.
APEX-EPH-07	"Software Test Report for the APEX Orbital Data Processing System Ephemeris Computation Function", Radex,Inc. February 8, 1993.
APEX-IDD-00	"Interface Design Document for the APEX Orbital Data Processing System, RMS Technologies, Inc., April 20, 1992.
APEX-TDP-01	"Software Requirements Specification for the APEX Orbital Data Processing System Telemetry Data Processing Function", Calculex, Inc., December 02, 1991.
APEX-TDP-02	"Software Detail Design Document for the APEX Orbital Data Processing System Telemetry Data Processing Function", Calculex, Inc., April 20, 1992.
APEX-TDP-06	"Software Test Procedure for the APEX Orbital Data Processing System Telemetry Data Processing Function", Calculex, Inc., May 5, 1992.
APEX-TST-05	"Software Test Plan for the APEX Orbital Data Processing", RMS Technologies, Inc., December 10, 1991.
APEX-TST-06	"System Level Test Procedures for the APEX Orbital Data Processing", RMS Technologies, Inc., May 17, 1991.
APEX-TST-07	"Software Test Report for the APEX Orbital Data Processing", RMS Technologies, Inc., August 7, 1991.
APEX-TUP-01	"Software Requirements Specification for the APEX Orbital Data Processing System Telemetry Unpack Function", RMS Technologies, Inc., December 10, 1991.
APEX-TUP-02	"Software Detail Design Document for the APEX Orbital Data Processing System Telemetry Unpack Function", RMS Technologies, Inc., April 20, 1992.

APEX-TUP-03	"Software Product Specification for the APEX Orbital Data Processing System Telemetry Unpack Function", RMS Technologies, Inc., August 3, 1993.
APEX-TUP-04	"Software User's Manual for the APEX Orbital Data Processing System Telemetry Unpack Function", RMS Technologies, Inc., December 1, 1992.
APEX-TUP-06	"Software Test Procedure for the APEX Orbital Data Processing System Telemetry Unpack Function", RMS Technologies, Inc., April 20, 1992.
APEX-TUP-08	"APEX Telemetry Unpack Function, Code Listing Notebook", RMS Technologies, Inc., August 7, 1992.
CI-80501-10	"CTU-2001 Time Merge Unit Technical Manual", Calculex, Inc., March, 1991.
CI-80501-35	"Analog Tape Database User Manual", Calculex, Inc., January, 1993.
CI-80501-57	"Archive Database Program User Manual", Calculex, Inc., June, 1994.
CI-80501-11	"Data Acquisition Software User Manual", Calculex, Inc., March, 1991.
CI-80501-13	"Quality Check Program User Manual", Calculex, Inc., March, 1991.
CI-80504-01	"CTS 3100 FM to PCM Converter Technical Manual", Calculex, Inc., April, 1994.
CI-80501-38B	"Work Request Database User Manual", Calculex, Inc., March, 1991.
MSTI-2-AGY-ICD	"Agency File Format Interface Control Document for MSTI-2", Boston College Institute for Space Research, Inc., June 22, 1994.
MSTI-2-ATG-REQ	"Software Requirements Specification for the MSTI-2 Orbital Data Processing System Agency Tape Generation Function", RMS Technologies, Inc., June 15, 1993.

MSTI-2-ATG-PRD "Software Product Specification for the MSTI-2 Orbital Data Processing System Agency Tape Generation Function", RMS Technologies, Inc., August 2, 1993.

MSTI-2-ATG-COD "MSTI-2 System Agency Tape Generation Function, Code Listings", RMS Technologies, Inc., August 2, 1993.

MSTI-2-ATT-REQ "Software Requirements Specification for the MSTI-2 Orbital Data Processing System Attitude Processing Function", Radex, Inc., June 15, 1993.

MSTI-2-ATT-PRD "Software Product Specification for the MSTI-2 Orbital Data Processing System Attitude Processing Function", Radex, Inc., August 2, 1993.

MSTI-2-DFC-REQ "Software Requirements Specification for the MSTI-2 Orbital Data Processing System Data Flow Control Function", RMS Technologies, Inc., June 15, 1993.

MSTI-2-DFC-PRD "Software Product Specification for the MSTI-2 Orbital Data Processing System Data Flow Control Function", RMS Technologies, Inc., August 2, 1993.

MSTI-2-DFC-COD "MSTI-2 System Data Flow Control Function, Code Listings", RMS Technologies, Inc., August 2, 1993.

MSTI-2-EPH-REQ "Software Requirements Specification for the MSTI-2 Orbital Data Processing System Ephemeris Computation Function", Radex, Inc. June 15, 1993.

MSTI-2-EPH-PRD "Software Product Specification for the MSTI-2 Orbital Data Processing System Ephemeris Computation Function", Radex, Inc. August 2, 1993.

MSTI-2-SYS-CMP "Configuration Management Plan for the MSTI-2 Orbital Data Processing System, RMS Technologies, Inc., September 1, 1993.

MSTI-2-SYS-IDD "Interface Design Document for the MSTI-2 Orbital Data Processing System, RMS Technologies, Inc., September 1, 1993.

MSTI-2-SYS-PSD "Programming Standards Document for the MSTI-2 Orbital Data Processing System, RMS Technologies, Inc., September 1, 1993.

MSTI-2-SYS-QAP "Quality Assurance Plan for the MSTI-2 Orbital Data Processing System, RMS Technologies, Inc., September 1, 1993.

MSTI-2-TUP-REQ "Software Requirements Specification for the MSTI-2 Orbital Data Processing System Telemetry Unpack Function", RMS Technologies, Inc., June 15, 1993.

MSTI-2-TUP-PRD "Software Product Specification for the MSTI-2 Orbital Data Processing System Telemetry Unpack Function", RMS Technologies, Inc., August 2, 1993.

MSTI-2-TUP-COD "MSTI-2 System Telemetry Unpack Function, Code Listings", RMS Technologies, Inc., August 2, 1993.